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The "ARMY AVIATION DIGEST" is an official publication of the Department of the Army published monthly under the supervision of the Commandant, Army Aviation School. The mission of the "ARMY AVIATION DIGEST" is to provide information of an operational or functional nature concerning safety and aircraft accident prevention, training, maintenance, operations, research and development, aviation medicine, and other related data.

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ARMY AVIATION
DIGEST

VOLUME 1 | FEBRUARY 1955 | NUMBER 1

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Publication of the ARMY AVIATION DIGEST is another mark of progress in the Army's efforts to achieve a more mobile and versatile fighting force. The vital importance of organic aviation has been proven on the battlefield. The principles governing its application are being constantly evaluated in order to assist the soldier to carry out his vital task of enhancing the security of our Nation. I am confident that the ARMY AVIATION DIGEST will be of great value in stimulating professional military discussion and in disseminating information concerning the increasingly important role of Army Aviation.

M. B. Ridgway

M. B. RIDGWAY
General, United States Army
Chief of Staff

AERIAL EQUILIBRIUM

Colonel William H. Byrne, *Medical Corps*

The views expressed in this article are the author's and are not necessarily those of the Department of The Army or of the Army Aviation School.—The Editor.

When birds in flight enter clouds, fog, or any similar medium, they immediately establish a glide and prepare to land. The reason for this action on the part of such accomplished fliers is that they have lost their VISUAL REFERENCE, such as the horizon. Being less apt at flying than the avian class of vertebrates, the improperly trained or inexperienced pilot under similar conditions is often less fortunate in his landings. The latter would not occur so frequently if all pilots of modern aircraft under blind flight conditions would learn to use and trust the reliable visual references which they have available on the instrument panel, such as the gyro-horizon flight indicator and other instruments.

What causes the mistrust and disregard of the instruments which the pilot knows are accurate and reliable? The mistrust is the result of the pilot being the victim of improper utilization and coordination of three of his senses, sight, muscle sense, and vestibular sense, which, if coordinated, will maintain equilibrium. Stimuli to the brain from one of these senses may produce independent action without any conscious regard to the outcome. Thus, sensory illusions are often produced.

Sight is our most reliable sense, possibly because in the presence of adequate light the stimuli formed and sent to the brain are less subject to misinterpretation by the visual center. In the absence of adequate light, sensory illusions pertaining to vision do occur with an appreciable frequency. Muscle sense (deep sensibility) is variable in its response and of much less importance in the production of sensory illusions. Because of the relatively great sensitivity and power of the vestibular sense and the unreliability of it when acting in the absence of visual reference, it produces illusions more frequently than the other senses.

The vestibular apparatus, which is frequently concerned with sensory illusion, is composed of three fluid-containing semicircular canals arranged in the horizontal, vertical, and transverse planes within the bony structure of the inner ear. The dilated end of each canal, the ampulla, contains hair-like processes (nerve endings) that are stimulated by the movement of the fluid in the canals. In order to stimulate the above processes by linear movement, the rate must exceed 12 cm per sec per sec. Rotary movement must exceed 2 degrees per sec per sec in order to produce a stimulus. This fluid is analogous to a glass container of water. For example, when the container is quickly rotated, the fluid lags behind because of inertia. When the container is suddenly stopped, the momentum continues to rotate the fluid in the glass. Likewise, if the glass is rotated very slowly, the fluid moves with the container and there is no function between the fluid and the glass.

Illusions

The tilting illusion, which is commonly called the "leans", occurs following the detection of a rapid change in the attitude of a wing by the semicircular canals if the wing returns to the level position too slowly to be detected. The illusion is so convincing that the pilot will lean away from the original tilting in spite of the indications of level flight by the instruments.

The turn illusion is produced by a gradual turn undetected by the vestibular system. However, when a rapid recovery is made, the fluid of the semicircular canals continues to move in the direction of the original turn. This produces the illusion of turning in the opposite direction.

If a pilot, during an instrument turn, lowers his head in the cockpit this maneuver often stimulates another semicircular canal to produce the illusion of a snap-roll.

The climbing illusion is frequent during flight in rough weather. It is produced by updrafts that increase the pressure on the seat which in turn affects deep sensibility, thus causing the flier to initiate action to correct an attitude of the aircraft that does not exist. This same sensation of climbing is frequently present in the execution of a turn. Downdrafts will produce the opposite sensation, that of descending.

The visual illusion that is the most dangerous usually occurs in the night formation flying. It results when a wing man stares at a wing light over an extended period of time and suddenly sees

the light move up or down. If he follows his intuition he will either turn away from or into the other aircraft. This is called autokinesis. Pilots have also landed on piers when they mistook parallel rows of lights for a runway. The most common illusion occurs during daylight flying between two cloud banks which slope toward each other and obstruct the view of the horizon. This produces an illusion of tilting and the flier, in an attempt to correct for a non-existent condition, will actually tilt his aircraft.

Summary

The first important fact that the pilot must learn and accept is that in the best of health he will have sensory illusions so long as he continues to fly.

The second important fact is that one must train himself to mistrust his intuition, to accept the illusions, and place his faith in the instrument panel.

A third fact of great importance is the training and utilization of the sense of hearing toward adopting radio-navigational aids and procedures in order to increase his confidence in instruments during IFR conditions.

Instrument flight is an ever increasing necessity in the course of military flying, and each pilot is obligated to become well qualified and maintain proficiency in instrument procedures under IFR conditions.

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FLYING THE THUNDERSTORM

Major Joseph H. Hall, *USAF*

The views expressed in this article are the author's and are not necessarily those of the Department of The Army or of the Army Aviation School.—The Editor.

The thunderstorm represents a violent and spectacular form of atmospheric convection. In its method of development it appears to be a cumulus cloud gone wild. Lightning and thunder, usually gusty surface winds, heavy rain, and occasional hail accompany it. These phenomena are indicative of violent motions and complex physical processes going on within the cloud.

As the atmosphere becomes unstable, regardless of cause, it undergoes convective overturning. This convective overturning, because of the non-uniform character of the atmosphere, and the release of energy through the phase change of water at the condensation and freezing levels, is seldom if ever uniform. Studies have shown that this non-uniformity results in a much wider area of downflow than in upflow. Since continuity must prevail over long periods of time, mean upward speeds are much greater than mean downward speeds. Actually, the compensating downward motion is very slow and produces clear skies or only low clouds and growth-arrested cumuli. It is well not to confuse this settling, or mild downward motion with the strong downdraft which develops within the thunderstorm itself. In contrast to the settling or gentle downward motion, the stronger upflow produces the cumulus congestus and cumulonimbus clouds.

During the thunderstorm projects, conducted by the U. S. Air Force in 1946 and 1947, over the states of Ohio and Florida, it was found that a thunderstorm can consist of one or more individual thunderstorm cells. For the purpose of this discussion, the thunderstorm cell will be considered as an individual storm and not as part of a storm. It is well to remember that the pilot, while flying through a thunderstorm, may encounter several thunderstorm cells within a single storm.

The life cycle of a thunderstorm cell is divided naturally into three stages depending upon the direction and magnitude of the predominating vertical flow. They are: (1) cumulus stage—characterized by updraft throughout the cell; (2) mature stage—characterized by the presence of both updrafts and downdrafts at least in the lower half of the cell; (3) dissipating stage—characterized by weak downdrafts prevailing throughout the cell.

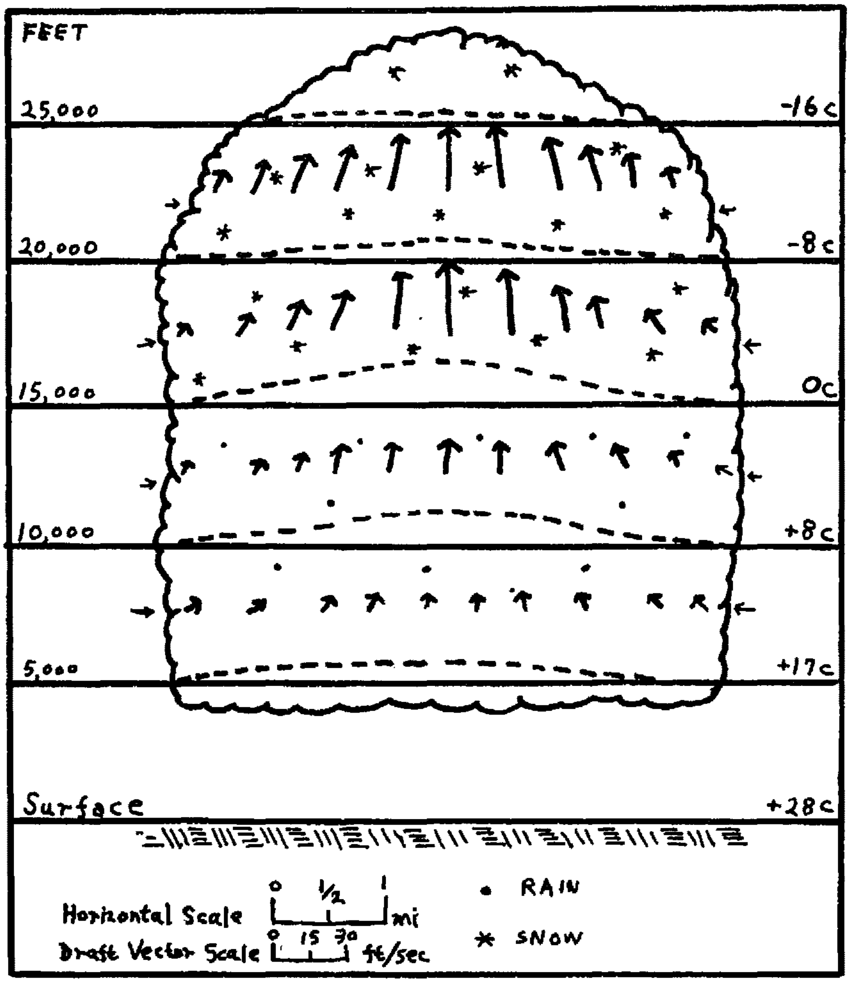
Development

Within the bulging cumulus, during the first stage of the cell's development, is an updraft that extends throughout most of the cloud. The presence of this updraft is reflected at the ground level by a region of slightly lower surface pressure and gently converging surface winds. As the updraft causes the cloud to extend in height, air flows in through the sides of the cloud (entraining) and mixes with the updraft, in response to pressure differences and various drag forces. With continued upward motion, a large amount of free water is liberated which in time exceeds the amount that can be supported by the updraft, and the water starts to fall. Because of viscous drag, aided by decreased thermal stability brought about by the entrainment of environment air, this falling water soon initiates a vigorous downdraft in part of the region which previously contained an updraft. This is the start of the mature stage of development. The downdraft develops at the expense of the updraft, and soon after the maximum downdraft speed is reached, the updraft is completely cut off from its source region and the cell enters the dissipating stage. With the dissipation of the updraft and the subsequent removal of the source of rainfall, the downdraft weakens and finally dies out completely.

In the initial stage every thunderstorm is, of course, a cumulus cloud, although only an extremely small number of cumuli actually continue their growth through the necessary stages to obtain thunderstorm proportions. On any particular day the number of thunderstorms that occur is determined in general by the instability of the atmosphere. Whether or not an individual cloud proceeds through the entire cycle of development depends upon peculiarities of its immediate environment.

Cumulus

The predominant feature of the cumulus stage of the thunderstorm cell is the updraft. Measurements made in cells in this stage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Horizontal Scale
0
1/2
1
mi
Draft Vector Scale
0
15
30
ft/sec
RAIN
SNOW

FIGURE 1

show that throughout the entire cell, from the lowest to the highest levels flown, the area is characterized by updraft. This upward motion may vary in both horizontal and vertical magnitude, as well as with time. Maximum speed in this stage occurs at the higher altitudes late in the period. Speeds as great as 50 feet per second are not unusual.

Observations made by flight crews show that the quantity of visible water and size of water particles in the cloud during the cumulus stage is small at first but continually increases with time. The greatest concentrations of hydrometeors—liquid, solid, or both—occur at the freezing level and above. While these hydrometeors are reported as rain or snow, they are occurring in an updraft, so their rate of fall relative to the earth is slight or even negative. In an updraft the hydrometeors may occur as liquid water, or rain several thousand feet above the zero isotherm. Still higher may be found a gradual transition from rain to snow and rain mixed, to wet snow, and finally to dry snow. The transition zone in which the water passes from a liquid to a solid state varies in depth, depending upon the speed of the updraft. This may be attributed to the likelihood that the water being carried upward does not change temperature as rapidly as does the ascending air, and that, accordingly, the drops continue to be warmer than the air surrounding them.

During the cumulus stage of development, the thunderstorm cell, which has an initial diameter of perhaps one to two miles, grows until its major axis is as great as six miles in length. It is difficult to establish a definite time duration for this stage, since it actually begins with the initial appearance of the cumulus cloud that is going to become the thunderstorm cell. If the duration is reckoned from the time the visible cloud top extends above the freezing level, it may be said that a cell usually remains in the building stage between ten and fifteen minutes. During this time, the visible cloud grows until its top reaches 25,000 or 30,000 feet. (Figure 1, page 8.)

Maturity

With the continued updraft during the cumulus stage, more and more vapor condenses, and the drops and ice crystals within the cloud become more numerous and increase in size. When the size, and consequently the mass, of individual drops or ice particles increases to such an extent that they can no longer be supported by the existing updraft, they begin to fall, relative to the earth. When

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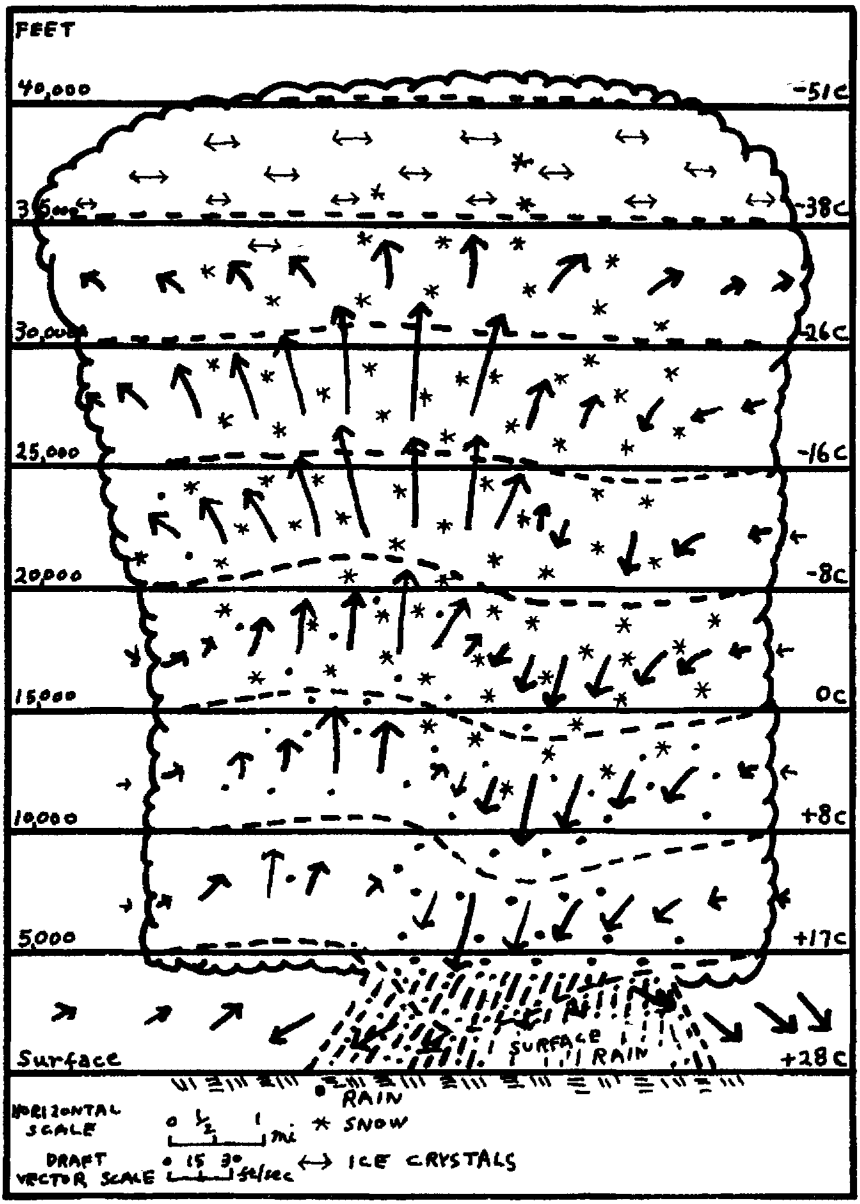
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0c
10,000
+8c
5,000
+17c
Surface
SURFACE RAIN
+28c
HORIZONTAL SCALE
0 ½ 1 mi
DRAFT VECTOR SCALE
0 15 30 ft/sec
• RAIN
* SNOW
↔ ICE CRYSTALS

FIGURE 2

this occurs, the thunderstorm cell has reached the mature stage. (Figure 2, page 10.)

In a portion of that area where measurements by airplanes have shown the primary movement of the air to be upward (in the early stage), a downdraft is now found. This downdraft is adjacent to the continuing portion of the updraft and has its greatest horizontal extent in the lower levels of the cell. The processes involved in its formation include the drag on the ascending air by the precipitation, which is falling relative to the air itself. This downdraft, which at first is found only in the middle and lower levels of the cell, gradually increases in horizontal and vertical extent. The downdraft speed in comparison with the updraft speed is more nearly constant with altitude, although a minimum below 5,000 feet is necessitated by the boundary afforded by the earth's surface. Above this region of deceleration, downdraft speeds of 40 feet per second are not uncommon.

The moving air of the downdraft does not come to rest at the surface of the earth, but changes its direction of motion as would any jet stream striking a plate. Thus, the vertical motion is transformed into horizontal motion and produces one of the most characteristic of the meteorological phenomena observed at the surface in conjunction with thunderstorms—the gusty surface current that flows outward from the area of rainfall.

During the mature stage of the cell, rain is found in the lower levels, snow and rain mixed in the middle levels, and usually only snow at the highest level flown by project airplanes. It is during the mature stage that hail occurs, although hail is not found in every storm. Above 26,000 feet, no direct observations have been made of hydrometeors, but from radar echos returned from cells in the mature stage of development, it is concluded that the size of individual particles and their number are probably large to heights of 60,000 feet in some cases.

At the surface, the area of heaviest rain is coincident with the area of maximum divergence in the surface winds. Since the rain is always falling, with respect to the air of the downdraft, the maximum rain occurs somewhat earlier than the maximum divergence.

Although turbulence might be classified as "heavy" by an experienced pilot flying in both cumulus and mature stages of a cell, it is during the mature stage that it reaches a maximum. It is strongest in the regions of the maximum updraft and downdraft

speeds, but definite zones of decreased turbulence, lasting for one or more 10-second or 3,000 foot intervals, exist between adjacent cells. Although least severe in the lowest altitudes, even there the turbulence at some points is usually great enough to be classified as "heavy".

As the rainfall continues throughout the mature stage of the cell, the downdraft area increases in size until, in the lower levels, it extends over the entire storm cell. This is considered to be the end of the mature stage, which usually lasts for a period of 15 to 30 minutes. During this stage the cell reaches its greatest height, which is normally above 40,000 feet, although an occasional cell extends higher than 60,000 feet and many complete the life cycle without extending higher than 30,000 feet.

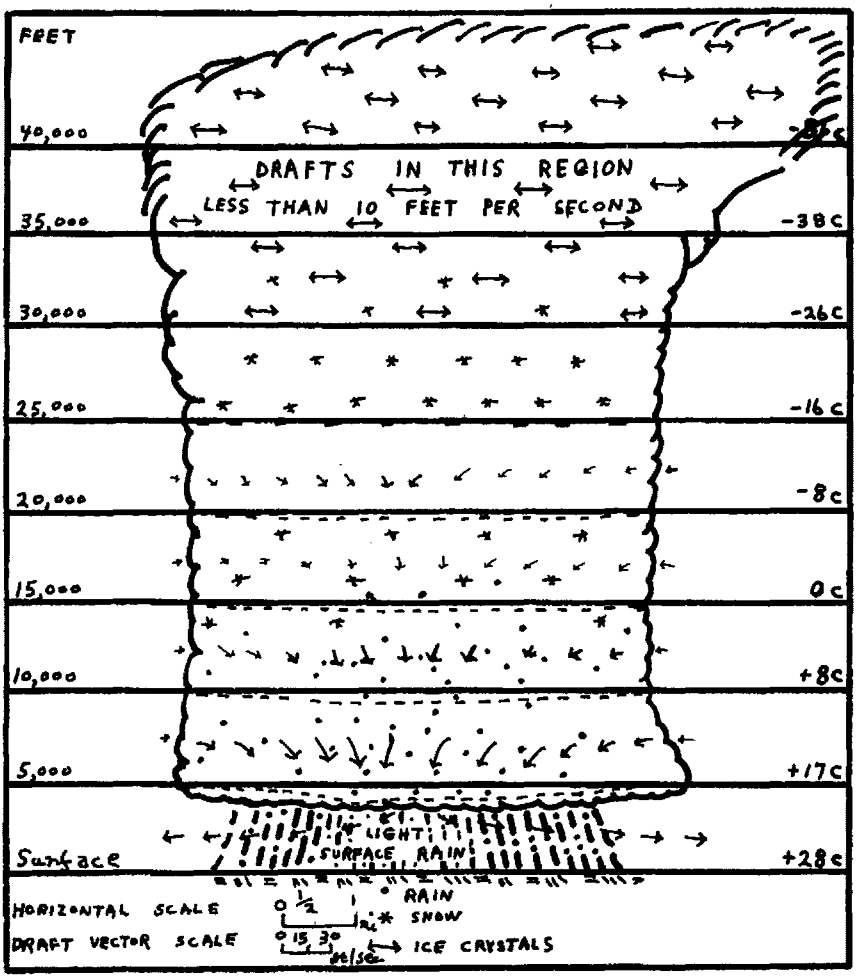
Dissipation

The downdraft, through the spread of its momentum and creation of new areas of descending air by the precipitation falling from the remaining updrafts, spreads rapidly over the entire area of the cell at successive higher and higher altitudes. During the dissipating stage of the cell's history, this process continues until the entire vertical and horizontal extent of the cell contains only downdraft or air with little or no vertical motion. As the downdraft expands laterally, the corresponding decrease in the volume of ascending air causes the total amount of liquid water being released within the cell to become progressively smaller. This reduces the mass of water available to accelerate the descending air.

Turbulence, too, becomes less severe with the reduction of vertical velocities in the drafts, although its intensity at some points is usually great enough to warrant a classification of "heavy" while the cell is in the early part of the dissipating stage.

As would be necessary, the liquid water encountered during this stage of the cell's development is less than when the cell is in the mature stage, and it continues to decrease with time. Correspondingly, the precipitation at the surface diminishes until finally the last residual drops have fallen. This may be as long as 20 minutes after the cessation of significant vertical motion in the cell.

The assignment of a definite time duration to the dissipating stage is difficult, since the thunderstorm frequently degenerates into layers of stratified cloud from which light, intermittent precipitation may fall for a considerable length of time. In general, however, the period from the beginning of this stage until the time when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DRAFTS IN THIS REGION
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35,000
-38 C
30,000
-26 C
25,000
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-8 C
15,000
0 C
10,000
+8 C
5,000
+17 C
LIGHT SURFACE RAIN
Surface
+28 C
HORIZONTAL SCALE
0 1/2 1
DRAFT VECTOR SCALE
0 15 30
RAIN
SNOW
ICE CRYSTALS

FIGURE 3

vertical motion within the cloud becomes insignificant is approximately 30 minutes. (Figure 3, page 13.)

The preceding discussion of the stages through which the thunderstorm cell passes in its life cycle presents a somewhat idealized situation, in which a unicellular storm develops and goes through a life cycle without additional cells developing in the adjacent area. While this frequently happens, it is seldom that such a cell attains a vertical development comparable to that of a cell in close proximity to other cells. It follows that the weather phenomena—such as rainfall, draft speeds, and high surface winds—associated with a cell of this type are considerably less intense than similar manifestations of a cell that is one of a group.

Multicellular Structure

From data collected by radar, it has been found that as a multicellular storm develops, each successive cell attains a greater height than did the previous ones. This occurs because lateral mixing across the boundary of cells which develop later would involve the saturated air from the earlier cells rather than the relatively dry air of the environment which completely surrounded the initial cell.

Research

In discussing the thunderstorm as it affects airplanes in flight, it must be remembered that the materials used are the studies developed from the U. S. Air Force thunderstorm projects, conducted over Ohio and Florida during 1946 and 1947. The airplane used was the P–61C, or Black Widow. The average speed flown was 180 mph. It follows that another type of aircraft, flying at a different speed, will be affected differently. It must be remembered also, that thunderstorm development, over other sections of the country, can be, and usually is, of different intensity.

Effects on Aircraft

The feature of the thunderstorm that flight crews denote as turbulence is a combination of gustiness and the effects of drafts. The drafts cause systematic changes in the altitude of a plane, whereas the gusts cause pitching, rolling, and yawing, and accelerations of the plane without a systematic change in altitude. Since studies made by the project indicated that the accelerations induced by the gusts were more important than the rolling and pitching effects in

the pilot's determinations of turbulence intensity, it follows that the degree of turbulence found in a thunderstorm is directly proportional to the airspeed. In addition to increasing the severity of turbulence, high airspeeds increase the airframe stress induced by the gust. It is easy to see, therefore, that in order to avoid increasing the severity of the turbulence and increasing the stress on the airplane, it is desirable to fly thunderstorms at an airspeed somewhat below normal cruising speed.

Turbulence

Thunderstorm project measurements showed that there is a distinct minimum of high-velocity gusts near the base of the storm. The maximum of high-velocity gusts were encountered above the 10,000-foot level. Because gust speeds are indicative of turbulence intensities, it must be concluded that, on the average, the least severe turbulence will be encountered by planes flying the lower levels of a thunderstorm, particularly near or below the cloud base. It is important to point out, however, that even though the turbulence at these low levels is at a minimum, it is frequently strong enough to be classified as "heavy to severe."

Drafts

As has already been stated, drafts are of secondary importance in the determination of turbulence intensity; however, they are of considerable importance because of the altitude displacements which may result when an airplane flies through them. This displacement depends upon the draft width and speed and upon the forward speed of the airplane. During the thunderstorm projects, upward displacements as great as 5,000 feet and downward displacements of 1,400 feet were encountered. Approximately half of all drafts encountered during these projects caused displacements greater than 500 feet; thus, if a pilot attempts to stay within the airspace assigned for his flight, he will find it necessary to apply corrective action to reduce this altitude change in approximately half of all drafts encountered. The resulting maneuver loads add to the gust loads applied to the airframe. Furthermore, the attitude of the plane resulting from attempting to combat the effects of the draft may lead to an inadvertent stall, or to a dive which may result in an increase in airspeed.

A very important part of the thunderstorm, especially to the pilot of a light airplane, is the cold downdraft that is found in the area of heavy rain; this downdraft continues below the base of the cloud and may, under certain circumstances, constitute a definite aeronautical hazard. As it approaches the ground it spreads out, as would a jet of water directed toward a flat plate, and forms a relatively cold layer of air over the surface. Indications are that significant downdrafts may exist at altitudes of less than 1,000 feet; however, the only place where the downdraft beneath the cloud base is likely to have a speed great enough to be hazardous to airplanes is in the rain core.

Hail

Hail is regarded as one of the worst hazards of thunderstorm flying. In the flights through storms in Ohio, hail was encountered on 51 of the 812 traverses. A thorough analysis of the collected hail data was made, and it was found that hail usually occurs during the mature stage of cells having an updraft of more than average intensity. Maximum occurrence of hail in Ohio storms was at the 10,000 and 15,000 foot levels. No relationship between hail occurrence and the color of the cloud or a peculiar shape or intensity of the radar echo from the cloud could be found. There is little question that the frequency of hail in thunderstorms of the Kansas-Colorado region is higher than that found in Ohio thunderstorms. On the basis of the project data, it might be concluded that the bigger the storm, the more likely is the pilot to encounter hail.

Ice

There were too few instances of icing encountered in the project flights to permit conclusions as to how or where to fly to avoid this hazard. Indications were that the lack of icing in the project flights resulted from the fact that the speed of the planes did not allow them to remain in the cell core, where high liquid water concentrations are found, long enough to pick up a heavy coating of ice. On 22 July 1946, a project sailplane, spiraling upward in an updraft region of a cell, iced so heavily that the pilot lost the use of the elevator control surfaces. In this instance the sailplane had been in the cloud above the freezing level about 12 minutes.

The generation of strong electrical potential gradients is a characteristic phenomena of the thunderstorm. When the gradient exceeds a certain critical value, dependent upon the air density,

number, and size of water drops, etc., a crash discharge occurs. This discharge is known as lightning. An airplane flying through a thunderstorm may be struck by such a discharge. During the two seasons flown, 21 lightning strikes were reported. Many of them were only lightning seen on a traverse, which might indicate the importance of the airplane in bringing about the discharge. Most of the strikes occurred at the 15,000 foot level. Strikes were comparatively rare at the lowest flight levels.

Indications are that lightning does not occur until the top of the cell reaches a height where the temperature is less than $-20°$ C. Prior to that time, it may contain drafts and turbulence of major concern to a pilot; it therefore appears that he should not rely on lightning to give warnings of thunderstorm conditions.

Roll Cloud

The roll cloud, a horizontal vortex of air and cloud particles near the base of the thunderstorm, has been of great interest to aviation because of its visible motions and turbulence. Project data indicated, however, that it does not occur with every thunderstorm. In two years of observations there were five reports of this phenomena. Since a minimum of heavy turbulence was found at the lowest levels of project flights, indications are that the roll cloud is not as severe a flight hazard as has sometimes been thought. This leads to the conclusion that the roll cloud is held in awe only because it is strikingly visible, and that it is only a foretaste of what is to be found inside the cloud.

Penetration

It has been found that the greatest turbulence in the thunderstorm is associated with the highest water concentrations. This relationship was found to hold at all levels within the storm. The association obviously results from the fact that the gusts are largely induced by the drafts, and it is in the updraft that large quantities of water vapor are converted into liquid water which when it falls to the ground as rain causes a vigorous downdraft to develop. These associations further show the interrelationship between the cells and the weather (*continued on page 44*)

K-24 CAMERA IN CLOSE SUPPORT

Captain John Kusewitt, *Artillery*

The views expressed in this article are the author's and are not necessarily those of the Department of The Army or of the Army Aviation School.—The Editor.

Born of necessity and fostered by ingenuity, the close support photography mission of Army aviation has evolved rapidly. In the old days, the Army aviator or observer pushed a hand-held camera out the window, tripped the shutter, and that was the extent of aerial photography operations. Then came the Korean War. For a while the old, hand-held K–20 camera worked like a charm and a vast quantity of close support photography to fulfill the immediate need of combat commanders was produced with it. However, it soon developed that obliques, the only type shots available with the hand-held camera, were not enough. Vertical type shots were needed and there was too much delay between the taking of the pictures and their delivery to the ground commander in the procedures in use at the time. Since immediate coverage of critical points or small areas was frequently required, this delay created a gap in the commander's intelligence system.

A hue and cry arose for something to fill this gap and again, the ground commander called on Army aviation to satisfy his need. First, some bright fellow developed a field expedient vertical mount for the K–20 camera on the outside of the L–19 aircraft. This combination worked for a while and there was an abundancy of vertical photos for commanders. Although quality of the photos was not everything desired, it was adequate for the purpose.

Unfortunately, this situation did not last long. Cold weather came and the external mounting of the K–20 camera proved unsatisfactory. Photo missions became a race to take the pictures before either the camera shutter or the photographer froze. Many times both froze. Also, the enemy was not idle. Increased anti-aircraft fire prevented prolonged operation of L–19's over enemy territory at low altitudes with impunity as had been the case. Better equip-

ment was needed and the winning combination of the K–24 camera and the L–19 aircraft was discovered.

Since vertical photography presented the biggest problem, the K–24 camera was initially mounted in a field expedient type mount which permitted vertical photography only. The K–20 was still used for oblique photography. The K–24 was reliable and offered longer focal length lenses which permitted increased operational altitudes without reduced scales. Also, it produced a much better quality photograph with a square format which permitted easy enlargement for interpretation purposes.

The K–24 camera mounted in an internal vertical mount became the standard for Army aerial photography in Korea. Everybody had them, used them, and liked them. Although the cameras were initially issued with 12-inch lenses, enemy anti-aircraft fire increased and 20-inch lenses were procured to permit flying at a higher altitude without a sacrifice in the scale of the pictures produced.

New Mount

This setup put vertical photography in good shape. However, vertical photography could not do everything. There were still requirements for oblique photography and the K–20 was the only camera which could be used. It was not possible to take good oblique strips with it since it was hand-held. Also, the short focal length of the K–20, which required relatively low flight over the objective, was making large scale oblique photography an extremely dangerous and almost impossible mission due to the increased anti-aircraft fire. Obviously, a mount was needed which would permit the use of the K–24 camera for oblique as well as vertical photography. The British are old hands at aerial photography from light aircraft and provided the answer to the problem. They use an F–24 camera (twin sister of the K–24) in their Austors, Army observation type aircraft. They have a mount for their camera that permits not only vertical photography but also oblique photography through a wide variety of oblique angles. Out came the scrap iron and hacksaw again and a new camera mount for Army aviation was produced. It permitted mounting the K–24 camera in the L–19 aircraft for vertical and oblique photography in the same manner as the British F–24 was mounted in the Austors. It lacked some of the niceties of the British mount, such as spirit levels, tangent screw adjustments, and quick-change hardware. However, the mount was produced in

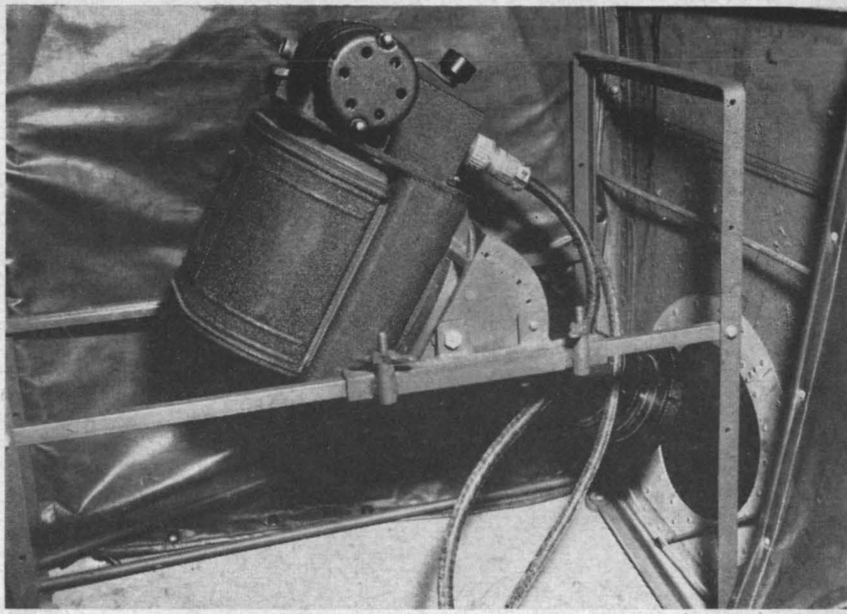
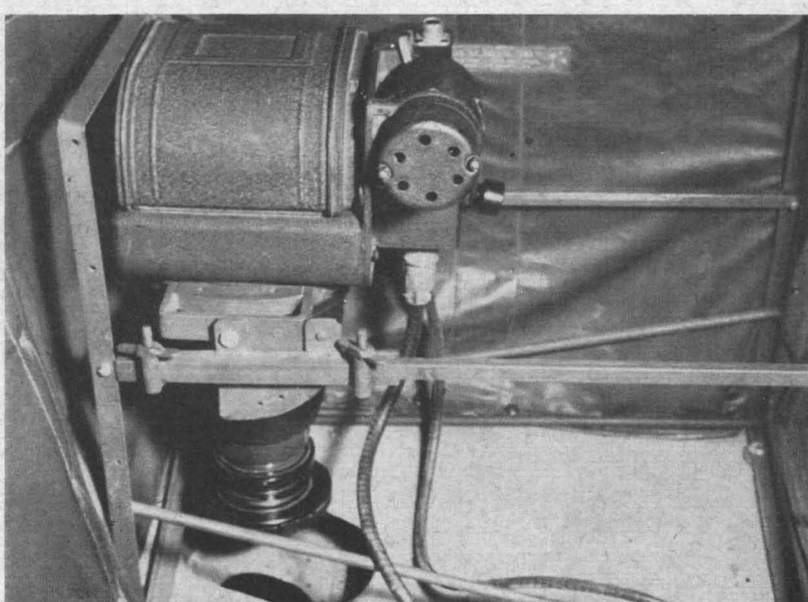


Figure 1 above shows the K–24 mounted in the baggage compartment of the L–19 type aircraft in position to take oblique photographs. Figure 2 below shows the camera in position to take vertical photographs.



ordnance shops and saw extensive service during the final months of the war.

Camera, Aircraft, K–24

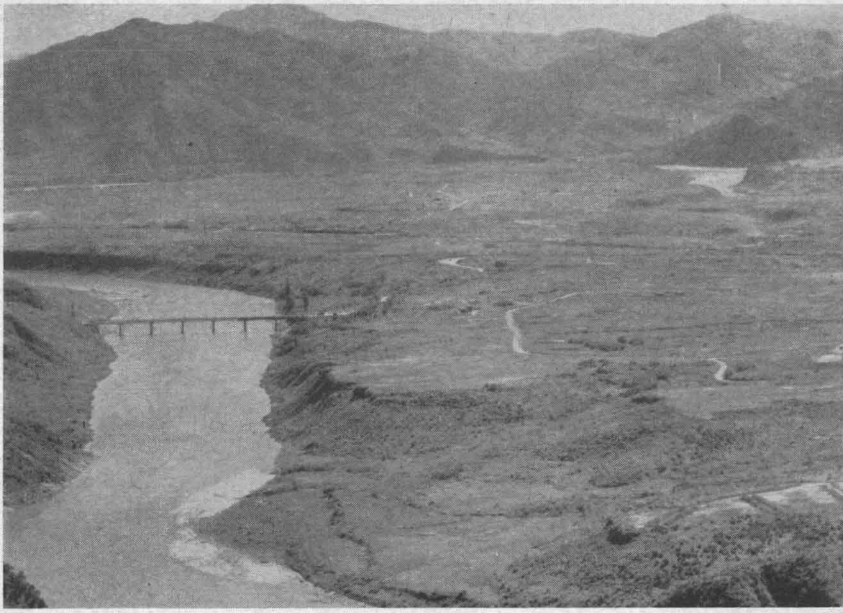
Let us examine this "camera, aircraft, K–24," and the manner in which it is used. It is a standard-type camera which has been in use since World War II. It produces a 5- by 5-inch picture which contains fiducial marks and a direction-of-flight arrow. The camera has interchangeable lenses, which are 7, 12, and 20 inches in focal length. Unlike small hand-held cameras, the K–24 has a focal plane shutter.

Several shutter curtains are provided with the camera to permit different shutter speeds to be used varying from 1/900 of a second to 1/150 of a second exposure time. Also, there is a night curtain for use with the night shutter stop position in night photography. However, night photography is beyond the scope of this article. The shutter may be activated by either a button on the camera or by a remotely located electric intervalometer.

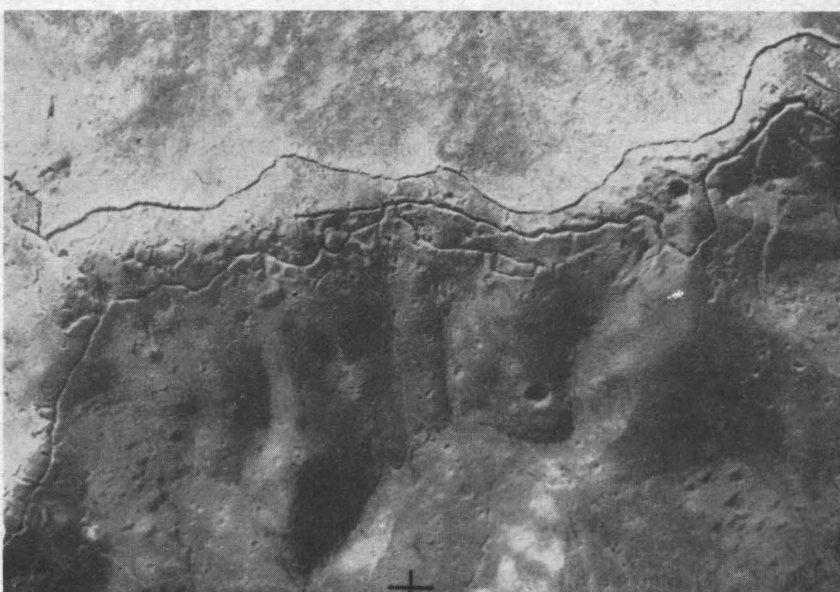
The camera uses roll film loaded in separate magazines which can be quickly installed or removed. Since the film does not have a light-proof leader, the magazine must be loaded and unloaded in a dark room or light-proof bag. Film comes in rolls 56 feet in length, enough for approximately 100 pictures per roll. The camera is equipped with a motor-driven film transport system which automatically advances the film and cycles the shutter after each exposure. Also, there is a hand crank provided to manually transport film and cycle the shutter when the night shutter is used or if the motor-driven system is not functioning. However, the camera is very rugged and reliable and few malfunctions occur. Infra-red sensitive film as well as standard aerial reconnaissance film may be used in the camera. When using infra-red film, a red filter should be used and the focus of the 12- and 20-inch lenses should be adjusted for infra-red.

Intervalometer

The majority of the K–24 cameras used in Korea were equipped with intervalometers to trip the shutters. The intervalometer is simply a timing device which will activate the camera shutter at regular intervals. It is adjustable so that any interval from "0" seconds (camera run way position) to 30 seconds may be selected dependent on the lens, altitude, ground speed, and overlap desired.



The above oblique picture was made with the K–24 mounted internally in the L–19 type aircraft. Below is a vertical-type photograph made with the camera in the same mounting.



The intervalometer is usually mounted in the L–19 on the left side of the cockpit so that it is accessible to both pilot and photographer.

Mount Design

The camera mount depicted in figures 1 and 2 on page 20 is the type currently used which was developed in Korea during the latter stages of the war. It provides a vertical position and oblique positions at 30, 45, 60, 75, and 80 degrees from the vertical. The base of the mount is attached to the floor of the L–19 baggage compartment by four bolts with sponge rubber grommets on the top and bottom to dampen vibration. Photography is accomplished with this mount through two lens ports. The vertical port, approximately 4½ inches in diameter, is located on the starboard side of the aircraft and outboard of the longitudinal stringers. The oblique port, approximately 6 inches in diameter is located in the port side of the baggage compartment. The mount has three adjustments. First, the two horizontal bars on which the carriage rides may be placed at various heights to position the lens at the port for the camera position used. Next, the camera mounting ring may be rotated within the carriage to position the camera at the desired vertical angle. Finally, the carriage can slide laterally on the rails and be clamped by the wing nuts in any position so as to align the camera axis with the camera port.

Although vertical sighting devices were not used in Korea, field expedient oblique sights were used. These sights consisted of rings painted on the pilot's left window and sighting posts mounted on the left wing strut which extended aft of the strut. The various rings and posts corresponded to the various oblique camera angles. By sighting through a ring corresponding to the angle at which the camera is tilted in the baggage compartment, aligning the corresponding post on the strut, then maneuvering the aircraft in such a manner that the ring, the post, and the objective are in line, the pilot aligns the camera to photograph the desired objective.

The camera, mount, and associated equipment described above were used on aircraft at division and corps level in Korea. Two aircraft per division were modified and at least one per corps artillery and corps. Modification of aircraft was accomplished under authority granted the theater commander in existing regulations.

The K–24 camera and the L–19 aircraft have proven an ideal combination for close support aerial photography by Army aircraft. Although the small format of the camera limits the area of coverage

at normal scale ranges, the requirements of close support photography are not for large area coverage but for spot, strip, or small area coverage of immediate interest to ground commanders. Furthermore, there are definite limitations in the processing available in tactical units so that attempts at large area coverage would soon bog down photo processing facilities. The negatives of K–24 cameras can be readily enlarged up to two diameters in field processing facilities without significant loss of resolution, thus making a more usable size for photo interpretation, restitution, and other detailed work. Tilt error in verticals, although in excess of that found in mapping quality photography, is within the allowable tolerance for tactical restitution and plotting work.

Lens

The K–24 permits a wide choice of lenses, altitudes, and camera angles allowing maximum flexibility in the choice of flight paths and altitudes for the aircraft flying the photographic mission. For example, with the 20-inch lens and 2 diameter enlargement in printing, the relatively large scale of 1/2500 can be achieved from an altitude of 8,000 feet. In practice, the altitude for verticals will extend from as low as 2,500 feet to as high as 12,000 feet depending on the scale, lens, and enlargement as well as tactical considerations such as enemy flak capabilities, cloud cover, terrain, etc. This same flexibility extends to oblique photography. Greater choice of altitude and ground distance to objective is available through proper selection of lens and camera angle. At higher oblique angles and using the 20-inch lens and 2 diameter enlargement, large scale obliques in the order of 1/3000 midpoint scale can be obtained at a ground distance of some 2 miles from the objective.

Photographer

Although a photographer is not necessary to accomplish photography with the K–24 mounted in the L–19, it is desirable to utilize one, particularly in vertical photography. A photographer can assist in aligning the aircraft for photo strips in vertical photography and relieve the pilot of the burden of setting the intervalometer and starting and stopping the camera. In addition, the possibility of light change over the objective makes it desirable to occasionally readjust the "f" stop for variances in light intensity to prevent improper exposure. Since most photo missions are flown for a single

type of coverage, there is not normally a requirement for changing camera positions in flight. Furthermore, with the field expedient mount described in this article, changing camera positions in flight is not practical since the mount requires approximately 10 minutes to set up in any particular position.

Value

The close support photography mission of Army aviation is here to stay. Although the K–24 camera and its field expedient mount in the L–19 is currently the best available solution to the problem, new standard mounts for the K–24 camera in the L–19 are being developed for issue. The K–24 or an equivalent replacement will be with us indefinitely.

The advantages of close support photography by Army aircraft have been fully recognized by commanders. The responsiveness of Army aviation elements to the commander, the timeliness of coverage, the ability to operate in marginal weather, and the reliability of coverage, permits the commander to obtain photography critical to the tactical situation which cannot feasibly be obtained by other means. Other services may take more pictures but, picture for picture, there is no comparison in value to the combat commander.

Captain John B. Kusewitt, Jr. is Chief, Research and Analysis Section, Combat Development Department, Army Aviation School. He received his B. S. degree from the U. S. M. A. in June 1945. He is also a graduate of the Army Basic and Advanced Artillery Courses and of the Army Aviation Tactics and Army Helicopter Aviation Tactics courses. During the Korean War he completed a combat tour with the Third Infantry Division as an Army aviator. He then was assigned as Operations Officer, Aviation Staff Section, Headquarters, Eighth Army, in Korea. While in this assignment, he supervised experimental work involving aerial photography from Army aircraft in combat.—The Editor.

ARMAV is now the official abbreviation for the Army Aviation School

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The Army Aviation School's 14 x 14 foot three-dimensional terrain board is complete with communications and simulated artillery bursts.

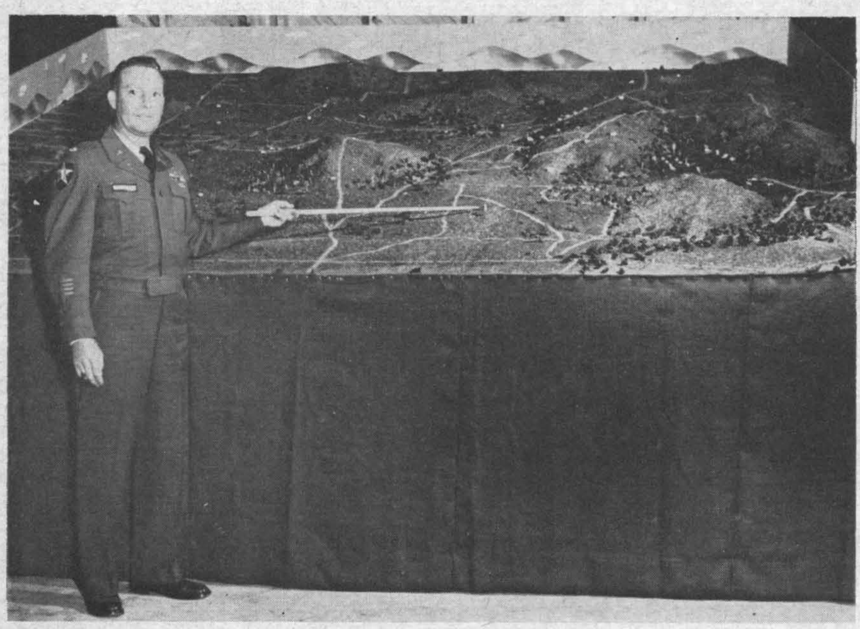
"FIRE MISSION!"

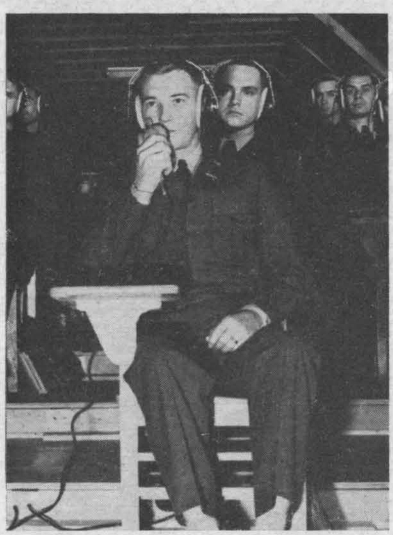
The Department of Tactics and General Subjects of the Army Aviation School at Camp Rucker, Alabama, has brought the outside inside with its artillery observer training aid. The three dimensional training aid was constructed with screen wire over a framework, small wood blocks, sponge, match sticks, and paint. Field artillery has also been brought inside by means of a few pieces of rubber hose, some small glass tubing, and the use of hydrochloric acid and ammonia with which to produce smoke. The training aid is 14 x 14 feet square and is a reproduction of terrain at Fort Sill, Oklahoma, on which artillery ranges are located.

A further sense of realism for the students is added by the communications system with which the board is operated. The system consists of a common network on which all students may transmit and receive from their classroom chairs.

The instructor acts as the Fire Direction Center. His assistant underneath the board puffs smoke up through the screen-terrain to simulate artillery bursts. As the students adjust their fire, the assistant shifts his smoke puffs accordingly.

The terrain above was made by placing screen wire over a framework, then covering it with colored sawdust. Note artillery bursts in center of picture. Below, instructor points out a base point on the board.





Left, student initiates fire mission.

Right, instructor lights burst panels above board to show the type of burst.

Below left, instructor's assistant puffs smoke up through the screen terrain to simulate artillery. Right, Captain Orville Y. Lyon, artillery instructor, shows sawdust of various colors, sponge, blocks of wood, rubber hose, and other materials used in construction of the board.

H-23 MAST BUMPING

ARMAV Monthly Safety Meeting

The Army Aviation School initiated its monthly safety meetings at Camp Rucker, Alabama, in November, 1954, with a forum-type meeting. A panel of four, consisting of civilian and military personnel, each an expert on a particular portion of the material which was to be presented, and a chairman, Major Hubert D. Gaddis, Tactics Commander, Rotary Wing Training, Army Aviation School, conducted the meeting. This method of presentation is not only interesting and entertaining, but is also an excellent means of disseminating safety information.

The following is presented to show the manner in which the meeting was conducted and to disseminate excellent information pertaining to control rotor stop banging in the H–23.—The Editor.

MAJOR GADDIS: "The subject of this safety meeting is one of great interest, not only to fully qualified helicopter pilots, but also to those in helicopter training, and to those who anticipate attending helicopter school. We have selected for our discussion control rotor stop banging in the H–23 helicopter. This aerodynamic phenomena has, in our opinion, been a direct cause of a series of accidents and incidents which have occurred in Army Aviation School. Although the correct title of this phenomena is control rotor stop banging, we also know it by several other commonly used terms such as mast rapping, stop banging, and mast bumping. When discussing this subject at AAS, the latter term is used most frequently. For the sake of simplicity we will, during this discussion, refer to it as mast bumping.

"Strange as it may seem, little if anything was known about mast bumping and its consequences until late 1953, when experienced helicopter pilots began to report near accidents due to an unexplainable loss of control during flight. This loss of control resulted in the helicopter rolling on its side and falling downward with a loss of from 100 to 300 feet altitude before control could be regained. No abnormal flight characteristics were noted by the pilots prior to the uncontrolled flight condition. Fortunately in these cases, sufficient altitude was available for safe recovery. Al-

though several theories were discussed during investigation of these incidents, nothing tangible was found on which the blame could be placed.

"Four of these incidents were forwarded to the manufacturer with a request for study which would explain inadvertent loss of control in the H–23. The manufacturer complied in this request and early this year (1954) reported that a loss of control was possible and probable if certain factors were favorable. However, before all pertinent factors were known and understood concerning mast bumping, and before preventative measures could be taken, two H–23 fatal accidents had occurred during student flight training. In each case, witnesses reported that judging from violent maneuvers of the helicopter, the pilots had apparently encountered a condition that resulted in loss of control from which they did not recover before striking the ground. A third fatal H–23 accident occurred recently and was similar in many respects to those preceding it, but there is doubt whether mast bumping was a primary or secondary cause.

"As a result of the striking similarity between the several near accidents and the fatal accidents, a special accident investigating board was convened to determine the definite cause or causes of them. This investigating board, furnished with pilots' statements, eye-witness reports of the fatal accidents, and the manufacturer's report which, if you recall, stated that loss of control was possible if certain factors were favorable, found that the factors in each case were indeed favorable and further found that mast bumping was the primary cause for the accidents. As a result of the H–23 accidents and of the accident board findings, the often used but never clearly understood phrase of mast bumping became a household word, so to speak, among student and rated pilots. As is the case when a particular type aircraft is involved in several fatal accidents, unfavorable rumors concerning the H–23 began to circulate. These rumors of course had their detrimental effect and immediately many individuals became gun-shy of the H–23, not realizing or understanding that mast bumping is the result of several important factors which can be controlled by the informed and safety-minded pilot. We are going to point out why mast bumping occurs, how it occurs, what factors cause it to come about, and how it can be prevented through sound precautionary measures and pilot techniques. Today, we have a panel composed of personnel assigned to the Army Aviation School whom we consider experts in their fields. First

member of the panel is Mr. William R. Gaines. Mr. Gaines, who is our Post Safety Director, was formerly a naval pilot and has considerable experience in many types of naval aircraft. Prior to his separation from active duty, he was in charge of instructor flight training at Pensacola Naval Air Base.

"Next is Captain R. V. Saunders, Jr. Captain Saunders will discuss the design factors of the H–23 including the aerodynamics and the mechanical characteristics of the ship which make mast bumping possible. Captain Saunders teaches all phases of H–23 design, aerodynamics, and maintenance in the Army Aviation School.

"Our next member is Mr. Ralph Greenway. Mr. Greenway is a helicopter standardization instructor in the school and has over 3,000 hours helicopter flight time. We consider him an authority capable of answering any questions relative to flight techniques necessary for recovery from mast bumping.

"Our last member is Captain Norman, the Army Aviation School Aircraft Maintenance Chief and an experienced helicopter pilot. Captain Norman's personal experience with mast bumping is of great interest. At this time I will turn the program over to Mr. Gaines, who will familiarize you with five incidents concerning H–23 helicopters."

MR. GAINES: "I have gone over the past accidents and incidents which we have had in the school as well as accidents occurring elsewhere in which we believe that mast bumping occurred. I have here a chart which shows many similarities in several of them. On this chart (Figure 1, page 32) are three accidents in which mast bumping was possibly involved and five more cases where we have definite indication that mast bumping occurred. Note that the following conditions existed in most of the accidents and incidents: The pilot had very little time in the H–23; the forward speed of the helicopter was from 50 to 65 knots when the accident or incident occurred; the center of gravity was either at or beyond its aft limitations; gusty or high wind conditions existed; and a loss of altitude occurred.

"It is possible that we are having more incidents involving mast bumping than are reported since many of them are apparently not recognized as mast bumping.

"I would like to summarize a two-eight-five accident report received from Fort Riley, Kansas, in which mast bumping is not mentioned. This report is very similar to those which we received

INCIDENT OR ACCIDENT				KNOWN CASES OF MAST BUMPING				
	1*	2*	3*	4	5	6	7	8
SOLO OR DUAL	SOLO	SOLO	SOLO	SOLO	SOLO	DUAL	DUAL	DUAL
CENTER OF GRAVITY	AFT	AFT	AFT	AFT	AFT	FWD	FWD	AFT
BALLAST USED	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE
TIME IN H-23	3 HRS	16 HRS	10 HRS	7 HRS	UNDER 100 HRS	UNKNOWN	OVER 500 HRS	100 HRS
FORWARD SPEED	UNKNOWN	65 KTS	30 KTS	60 KTS	50 KTS	55-60 KTS	50-60 KTS	50-55 KTS
PRIMARY CAUSE	UNDETERMINED	OVERCONTROLLING	LOSS OF TAIL ROTOR DRIVE SYSTEM					
CONTRIBUTING FACTOR	POSSIBILITY MAST BUMPING	MAST BUMPING	NONE					
WIND CONDITIONS	NO FACTOR	NO FACTOR	NO FACTOR	GUSTY 25-35 KTS	GUSTY 25-37 KTS	GUSTY 25-37 KTS	STRONG GUSTY 40 KTS	GUSTY 30 KTS
LOSS OF ALTITUDE				200 FT	400 FT	150 FT	300 FT	150 FT

*DENOTES ACCIDENTS

FIGURE 1

concerning known mast bumping incidents. It contains almost the same evidence as that which is presented in the eight reports which we have seen in the chart. However, mast bumping is not considered at all by the accident investigating board. The pilot had over 2,000 hours flight time but only seven hours in the H–23. The helicopter was flying at an altitude of 300 to 400 feet above the ground at an air speed of approximately 60 knots with all instruments and flight controls functioning normally. The wind was very gusty. The pilot stated that without warning the aircraft nosed up slightly, then pitched forward, attaining an air speed of over 85 knots which is well above the authorized maximum speed. All efforts to regain control failed. Pitch and cyclic controls were ineffective until the aircraft was approximately 30 feet above the ground at which altitude the helicopter leveled out just prior to striking the ground. Fortunately, there were no injuries, but the helicopter was demolished.

"In summarizing this accident, we find that a 350 foot loss of altitude occurred before control was regained; air speed was around 60 knots; the weather was very gusty; and the pilot was flying solo which means that his center of gravity was probably aft of its limitations unless ballast were used. We have no indication whether or not it was used in this case. Finally, the pilot's flight time in the H–23 was only seven hours and overcontrol would be very possible. These conditions are typical of those noted in the known mast bump-

ing incidents and it is highly probable that this pilot experienced mast bumping.

"The recommendation on this report was that helicopter pilots should be more thoroughly indoctrinated on helicopter flight characteristics under extreme weather conditions.

"I have pointed out the conditions which existed when mast bumping occurred since the recognition of the problem is the first step to the solution. At this time, I will turn the program over to Captain Saunders, who will discuss the aerodynamics and mechanical characteristics of the H–23 which makes mast bumping possible."

CAPTAIN SAUNDERS: "The information which I will present is based on results of study and tests by the engineers and test pilots at the Hiller factory. It is essential that we understand a few of the basic principles in the design of the semi-rigid, teetering type rotor system. In this type of system, some means must be devised to limit the teetering or flapping angle of the main lifting rotors. In the H–13, this flapping angle is limited by the use of dynamic stop cables which are attached to the stabilizer-bar frame and to the gimbal-ring pillow blocks. In the H–23, this flapping angle is limited by the main rotor drive shaft and the hollow bore of the main rotor hub. This is an approved part of the design of the H–23 rotor system. It is not accidental that the main rotor hub is allowed to contact the mast.

"Most of the difficulty encountered in the military services with this type helicopter, particularly when the aircraft is used as a basic trainer, involves overcontrolling. However, this is only part of the picture.

"What does happen when mast bumping is encountered? When a helicopter encounters an updraft in forward flight, its lifting rotor tends to tilt back. This rearward tilt, in turn, causes the helicopter to nose up. If the pilot's attention is momentarily diverted by other duties, a substantial nose-high attitude develops before he can again give his attention to correcting the attitude of his machine. Also, there will be an increased lag in control response with application of forward cyclic control stick.

"This combination of an unexpected, substantial change in attitude of the helicopter, combined with reduced control response, encourages less experienced pilots to overcontrol. They tend to quickly apply and hold full forward stick.

"In forward flight, the tip path plane of the H–23 control rotors

will always pass lower in the forward 360 degree position than the tip path plane of the lifting rotors. This is necessary to reduce the angle of the advancing lifting rotor and increase the angle of the retreating lifting rotor so that the entire tip path plane will incline forward for forward flight. In the H–23, the main rotor hub is underslung beneath the pivot center of the gimbal ring. The circular bore in the bottom of the main rotor hub serves as a mechanical stop which limits the flapping angle of both the control rotors and the lifting rotors. It is from this condition of the main rotor hub contacting the mast, that the term known as "Mast Bumping" originates. However, the mast bumping which causes the apparent loss of control is the result of violent contact between the hub and the mast.

"As I mentioned previously, the control rotor tip path plane must always be tilted forward of the lifting rotor tip path plane in forward flight. Thus, the control rotor side of the hub is always the first part of the hub to contact the mast in forward flight. Upon sudden, full application of forward cyclic stick, it will bang the mast as it passes the forward azimuth or 360 degree position.

"When this occurs, the control rotor blade rebounds, to reach a high point 90 degrees later at the left side or 270 degree position of the helicopter. This puts cyclic pitch into the lifting rotor which causes its blades to pass high on the left and results in tipping the entire tip path plane of the lifting rotors to the right. This accounts for the helicopter rolling to the right when pilots have encountered mast bumping.

"In addition to this rolling to the right, the nose of the helicopter will drop and a loss of altitude will result. As the nose of the helicopter continues to fall, the disc load carried by the lifting rotors drops.

"This disc loading can more easily be compared with wing loading in fixed wing aircraft. We all know that as forward airspeed decreases in fixed wing aircraft, there is an accompanying decrease in control response, especially lateral control. In helicopter aerodynamics, the same principle holds true in that the rotor disc takes the place of the fixed wing. As the disc load drops, there will be a loss of control response. In helicopters this means that the fuselage will not follow the rotor blades due to the loss of pendular action of the fuselage. A comparison can be drawn by placing the helicopter on the ground with the collective pitch reduced to its maximum low pitch position and then moving the cyclic control stick around its full travel. Naturally, there will be no response to this cyclic con-

trol by the helicopter fuselage since there is no loading on the lifting rotors. As a result of the loss of disc loading, the pilot experiences considerable lag in control response and the aircraft will lose altitude. Thus, it appears to the pilot that he has lost control of the helicopter.

"Now I would like to discuss certain factors which favor this condition of mast bumping. These factors are in the order of importance: (1) overcontrolling, (2) gusty or turbulent wind, (3) aft center of gravity position, (4) high forward air speed, and (5) low rotor RPM.

"Each of these conditions adds to the possibility of encountering mast bumping and usually they work in a combination of one or more. Fortunately, all may be easily recognized by the pilot and preventive measures can be taken when planning and conducting a flight.

"The factor which is overlooked by most pilots is the center of gravity location. The H–23 helicopter is designed so that the weight of the pilot will move the center of gravity forward into its normal limit of travel. However, this does not hold true in the case of a pilot weighing less than 150 pounds. A pilot who is flying with an aft center of gravity condition must hold excessive forward cyclic control which decreases the clearance between the main rotor and the mast. This condition, in conjunction with any of the other factors, greatly increases the possibility of mast bumping. A pilot should consult the Weight and Balance Data Handbook and ascertain that his center of gravity travel is well within limits.

"I would also like to mention briefly the factor of low rotor RPM in conjunction with gusty or turbulent wind. As rotor RPM decreases, we lose rotor disc loading. There is also a loss of centrifugal force which, in the H–23 design, is necessary to keep the main rotor hub centered around the mast. With the RPM drop and decrease of centrifugal force, the lifting rotors become mushy and unstable and are much more susceptible to gusty wind or turbulence. Thus, low rotor RPM contributes to the possibility of mast bumping.

"To alleviate the possibility of mast bumping, we must be cognizant of what happens when it occurs and avoid the errors, which singly or in combination, cause it. We must avoid overcontrolling, flight in extreme gusty or turbulent wind conditions, having our center of gravity location out of limits, high forward air speed, and low rotor RPM.

"Mr. Greenway, our next speaker, will tell you what corrective action can be taken if you should encounter mast bumping."

Mr. GREENWAY: "Those of you who are presently attending helicopter flight instruction courses are learning the techniques you use in recovering from mast bumping. They are simple. Your instructor is teaching you to use a slow, smooth cyclic control pressure in order to avoid overcontrolling. Not only will the application of this teaching make you a good all-around pilot, but it will help prevent mast bumping and in the event it should occur, will enable you to recover.

"If, during flight, your helicopter should assume a slightly nose-high attitude, due to a gust or updraft, ride with it. Use a slow, smooth cyclic pressure with a minimum displacement of the cyclic stick from the neutral position to recover. As Captain Saunders mentioned, the rotor system is unloaded with a nose-high position and there will be a slower cyclic reaction. Do not become impatient and displace the cyclic control an excessive distance from the neutral position. Ride with the helicopter.

"If the helicopter assumes an extremely nose-high attitude, maintain a neutral cyclic position and smoothly, slowly execute a pedal turn. As the nose returns to the horizon, stabilize the airspeed and maintain level flight attitude with the cyclic control.

"If you should experience mast bumping and roll to the right, ride with the helicopter, and again initiate a slow, smooth cyclic pressure which will cause the helicopter to return slowly to the level flight attitude.

"There is usually a loss of RPM when you experience mast bumping. This RPM must be regained. You must maintain the required centrifugal force on the blades in order to recover. To regain it, increase the throttle and ease the collective pitch down slightly. Lower it only that amount which is required to regain the RPM. Do not enter autorotation. Since you are pressing forward with the cyclic, the rotor is already slightly unloaded. If you enter autorotation, you unload the rotor completely and this results in a loss of the pendular action of fuselage of the helicopter. It then appears that the pilot has lost all control.

"Further, the amount which the collective pitch is lowered is proportionate to the amount of altitude which you will lose. If you lower the collective pitch excessively, you lose excessive altitude. If you lower the collective pitch only that amount which is required to reduce the drag on the main rotor system and permit you to regain your RPM, you lose a minimum altitude. Do not, when mast bumping is encountered, go into autorotation.

"If you encounter gusty wind conditions, the only factor contributing to mast bumping over which we do not have a direct control, and have rough flight control techniques, you may very possibly experience mast bumping. If you have gusty wind conditions and smooth flight control techniques, you can avoid mast bumping. Those of you who have flown fixed wing aircraft in gusty wind conditions have probably noticed that there is a certain rhythm in gusts. If you can anticipate when the gusts will hit the aircraft, you can lead them with slight pressures on the controls and dampen their effects.

"Overcontrolling is the most direct cause of mast bumping and causes the greatest difficulty in recovering from a mast bumping condition. Smooth flight control techniques prevent mast bumping and they must be used in recovering if the condition is encountered. At this time, Captain Norman will discuss two experiences which he has had with the mast bumping condition."

Captain Norman: "The information you have just heard is very important. I wish I had known it when I experienced my first mast bumping in 1951 at Fort Sill. I had recently completed helicopter school and was assigned as helicopter maintenance officer for the Army Aviation School. At the time of the incident, I had between 15 and 25 hours pilot time in the H–23. I was completing a test flight and was entering the traffic pattern north of Post Field at an altitude of 500 feet above the ground with an airspeed of approximately 60 knots. Suddenly the nose of my helicopter came up rapidly and the ship rolled to the right. I rammed the cyclic stick full forward. Naturally that aggravated the situation as we now know. I also noticed that my engine RPM was 2700. Again I did the wrong thing. I went down on the collective pitch stick rapidly. I do not recall all the other corrections I tried to make during my descent. It seemed that I had lost complete control of the helicopter. I don't know how I regained control, but when it leveled out I noticed that I had lost over 300 feet of altitude. I landed at Post Field as soon as possible. I questioned the flight commander and other pilots to see if they had ever had a similar experience. Two said that they had but had no idea what caused it.

"Approximately one month later, while on another local test flight, I was flying at an altitude of 500 feet at 70 to 75 knots and encountered mast bumping again. The helicopter went through the same initial gyrations. The nose rose and it rolled slowly to the right. I had given my first experience considerable thought and

concluded that I had greatly overcontrolled while trying to level the helicopter. This time I eased forward on the cyclic and down slightly on the collective. Slowly the helicopter returned to a normal flight attitude. I lost approximately 100 feet.

"Since my experiences, the Hiller engineers have explained many of the reasons for mast bumping and I now know that the cards were stacked against me. I weighed 132 pounds and on both incidents I had stayed out over an hour, which meant that I had less than one-half tank of fuel remaining. I was not using ballast and as a result my center of gravity was outside of its aft limits. I was flying over 60 knots, had low rotor RPM, and the wind was gusty. With these conditions existing, I greatly overcontrolled in the first incident. I was a little better in the second but still overcontrolled slightly.

"The Department of Army has also disseminated, in a letter from the Office of the Chief of Transportation, essentially the information which we have been given in this meeting concerning mast bumping. Mast bumping can be avoided and recovery from it can be made but a pilot must know what to do, how to do it, and when to do it."

MAJOR GADDIS: "In summary, I would like to explain briefly what the Army Aviation School has done to prevent mast bumping from contributing to or causing an accident. The following standard operational procedure has been established at the school:

(1) The H–23 will not be flown without proper ballast to bring the center of gravity into safe operating limits.

(2) The H–23 will be flown dual only in winds from 20 to 30 knots. Solo flight, properly ballasted, is limited to 20 knots. Additionally, the gust spread must not exceed 7 knots.

(3) The traffic pattern altitude will be a minimum of 700 feet for all helicopters. This gives a pilot more opportunity to recover from mast bumping if it should occur.

(4) All primary helicopter flight training for the cargo pilot students through their tenth week or until they have 50 hours will be conducted in the H–13 helicopter."

The Hiller Helicopter Company has recently redesigned the rotor hub so that mast bumping is highly improbable, and in the event that it does occur, the apparent loss of controls discussed above is not experienced.—The Editor.

INTRODUCTION TO HELICOPTER ETIQUETTE

Joseph S. Dunne

The views expressed in this article are the author's and are not necessarily those of the Department of the Army or of the Army Aviation School.—The Editor.

A recent exhaustive survey has revealed that some pilots are spending more hours with their helicopters than they spend with people.

Pursuing this further, we have discovered an alarming and entirely new social problem. "SOME PILOTS ARE INCOMPATIBLE WITH HELICOPTERS." In an attempt to stamp this thing out before it assumes major proportions, we are daring to present some of our own ideas on "PILOT-HELICOPTER RELATIONS" or "HELICOPTER ETIQUETTE."

First, to qualify ourselves for this task, we submit that we are experts in this new field. This position cannot be contested, since the field of "Pilot-Helicopter Relations" is so new. We do not plan to provide any information on how to get along with people. Our expertness applies only to getting along with helicopters.

Do you force your helicopter to fly in a skid? This one social error alone causes more unhappiness among helicopters than any other.

Helicopters don't like to skid. For every power setting there is a correct rudder setting, and if you want to get along with your helicopter you had better learn how to fly her with the correct amount of rudder. How?

There is an easy way to figure this out. The method may sound silly but we use it with success at the factory.

With scotch tape, fasten a ten-inch length of wool yarn to the center line of the bubble at pilot eye level. In flight adjust rudders until the yarn streamlines straight back over the canopy. Then make it incline about 5° toward the port side. Your rudders are now adjusted correctly for the airspeed and power setting at which you are flying. This "yaw meter" (yarn on the bubble) is not very expensive and you will be surprised how much you will learn from

it. We predict that you will find ways to improve your rudder technique and that this will go a long way toward improving relations between you and your helicopter.

Keep your helicopter happy and it will treat you right.

In line with this problem of "how to get along better with your helicopter," here are some DON'Ts on correct behavior:

Don't fly with loose, sloppy irreversibles. The tendency here (and it sneaks up on you) is to tighten up on cyclic friction and keep on flying. *This is bad!* Because while *you* may be happy, your poor helicopter is taking an awful beating in the irreversibles. To do this does not increase your popularity among helicopters. (It also wears out irreversibles, which cost money.)

Don't continue to fly with a poorly adjusted throttle cam. This sort of thing is going on all over, and helicopter engines all over the country are taking a lot of unnecessary punishment as a result of it. Get your cam fixed and the engine rpm will always be correct. Engines don't like to be changing rpm all the time.

Don't walk away from your helicopter without making sure that she's comfortable and secure. Tie down her rotor blades and close her doors. Above all, never walk off and leave her running. This is not only rude, but it is also dangerous.

Don't treat her rough *all* the time. When it isn't necessary to work her hard, let her coast a bit.

Don't ignore vibrations. She may be in pain. Maybe her main rotor or tail rotor is out of track or balance, or her bearings, or universals are worn.

There are lots of little niceties you can use to improve relations. Most of these little attentions are not more than you would show your best girl or wife, and after all if you're going to live with her, you might as well keep her happy. You'll get a lot more out of her.

Joseph S. Dunne is Chief Experimental Test Pilot for the helicopter division of the Bell Aircraft Corporation, Fort Worth, Texas. During the early part of World War II he served as an Air Force fighter pilot. In 1943, he entered helicopter training. Upon graduation, he served as a helicopter instructor until separated from active service in September, 1945. He joined the Bell Corporation in January, 1946, and participated in the formation of the Bell Helicopter Training School. In 1949 and 1950, he managed Bell's Oil Exploration Division in Louisiana. Since 1950 he has been doing experimental test pilot work.

Grey Hare Says

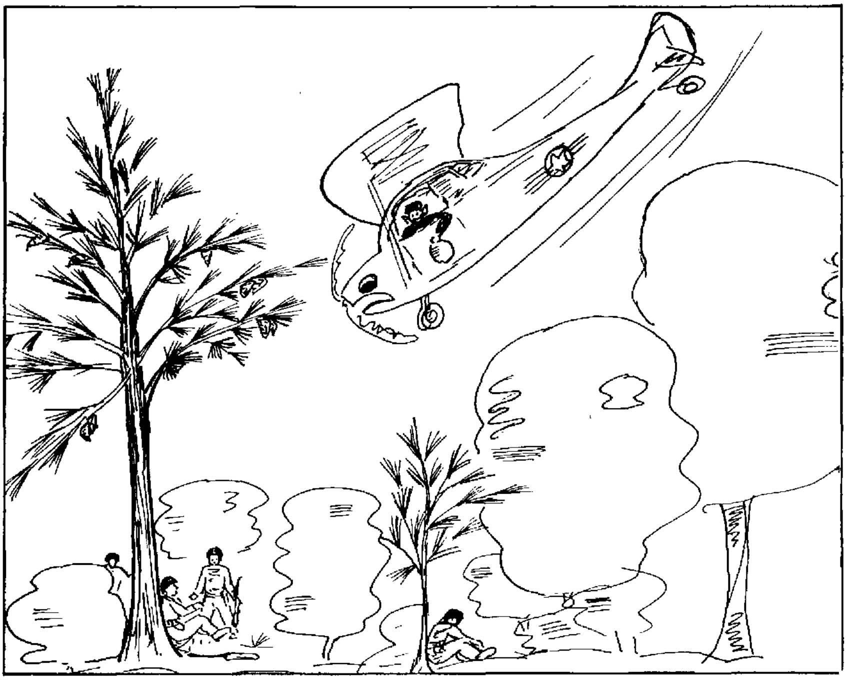
Four of a Kind

"In thumbing through the aircraft accident files for the first seven months of 1954, it is noted, with regret, that we have had one fatality and five serious injuries occurring under circumstances in which pilots were performing the same type mission."

Case No. 1. "Our pilot was assigned a simulated bombing and strafing mission. He arrived in the vicinity of the troops, made three passes and dropped flour sacks. On his fourth pass he flew into a tree, crashed and seriously injured himself and his passenger. The aircraft was totally wrecked.

Case No. 2. "Our pilot was again assigned a flour-sack bombing mission with a motor column as the objective. After making a low altitude bomb run on the column, he started a right turn and naturally dropped his right wing. The wing struck a tree eight inches in diameter and pulled the plane into the ground where it caught fire and was completely destroyed. Fortunately, although our pilot and passenger received serious injuries, they escaped with their lives.

Case No. 3. "As in the two previous cases, our pilot was on a flour-sack bombing mission and in this case he was unusually fortu-



nate. On his second pass at the tanks and troops, he decided to make a run farther to the left in order to get a direct hit. At very low altitude, he started a left turn, and as he lowered his left wing it struck a treetop. Our pilot recovered control of the aircraft and although he knew that he had hit a tree, he completed his passes at the tanks and troops before returning to base. He made a safe landing at his base and thus escaped without injury. However, damage to the aircraft amounted to $427.45.

Case No. 4. "In this case, two L–19A's were assigned the mission of flour-sack bombing a convoy. The first plane made one simulated attack. Our pilot in the second plane was making a 180° turn in preparation for an attack when he hit three high tension wires. The plane veered to the right, carrying the wires with it and crashed into the ground, right wing first. It immediately caught fire and was destroyed. The passenger was injured seriously and the pilot fatally.

Summary

"In reviewing the four cases, it is obvious that poor judgment on the part of the pilot was the cause of each accident. When a pilot is planning to fly a mission at low altitude, he should make a

high reconnaissance of the area and look for such things as high trees, ridges, power lines, and other high obstacles. The pilot should devote his full attention to flying the aircraft. Bombing should be accomplished by an observer. At all times, the safety of the aircraft should be given primary consideration and bombing accuracy, or even satisfactory accomplishment of the mission, should receive secondary consideration.

"As noted in several of the cases, when the pilot was flying at treetop altitude and started a turn, he naturally dropped his wing in the direction of the turn. The pilots evidently failed to realize that the wing tip was lower than the cookpit since their altitude with relation to the ground and the trees remained unchanged. In several cases the pilot evidently looked back, a serious mistake at low altitude, to see where his bomb hit.

"As an additional safety precaution while engaged in flour-sack bombing missions, a pilot should never fly less than 200 feet above the highest obstacle in the vicinity of his target. This will allow sufficient altitude in which to execute a normal turn.

"In each of the four cases above, the old saying in aviation, TOO LOW, TOO SLOW, TOO BAD, is applicable. Total aircraft damage was approximately $32,000. What is the dollar and cents value of five seriously injured personnel and one dead?"

Experience Versus Odds

"We have a case of a well-experienced pilot with total flying time of 1,250 hours of which 332 were flown in the L–19A during the past twelve months. Our pilot felt his experience outweighed almost any odds he might place against himself while flying the faithful L–19. With one passenger, our pilot elected to take off from a 528 foot unmarked strip of asphalt road. At the end of the strip was a barracks type housing area. Incidentally, some 400 yards away was a regular marked strip on which the pilot had formerly made a landing. Our pilot should have realized that had he gotten airborne from his short 528 foot strip he would have been endangering lives of personnel in the housing area. Faced with this short strip and buildings as obstacles, he proceeded to perform his pre-takeoff check. On his full power check, the engine developed 2,000 RPM. Our pilot knew that the engine should turn up 2,200–2,300 RPM at full power. Knowing that the engine was not operating properly our pilot still elected to take off and use maximum take-off procedure. During his take-off run, he later said, he realized that the aircraft was definitely not developing its normal power

and that he was not gaining flying speed as he should. However, he made no attempt to stop his take-off roll although he had ample opportunity to veer to the right across an open vehicle park which provided him a smooth stopping area 350 feet in length. Instead, he continued trying to force the plane off the ground until it struck a steel road sign at the end of the strip. Fortunately, our pilot and passenger escaped with minor physical injuries. Damage to the aircraft amounted to $7,940.00.

"One wonders just where the pilot's head was, and if up, how tight it was locked. If the pilot had been totally inexperienced we might overlook such outstanding errors in judgment.

"A margin of safety is excellent insurance regardless of a pilot's past experience. Why not take advantage of this insurance since it is not only the best available but also free."

Incident Reports Desired

Many potential aircraft accidents have become incidents through the resourcefulness and right action at the right time of Army aviators. The Grey Hare Department would like to receive reports of such incidents. Information should be sent to Editor-in-Chief, ARMY AVIATION DIGEST, Camp Rucker, Alabama.—The Editor.

(*FLYING THE THUNDERSTORM, continued from page 17*)
elements found within. It is apparent that the best position to fly a light airplane through a thunderstorm, if it must be done, is in the lower level, preferably below the cloud and through the lighter areas. It is well to remember that, when approaching an uncircumnavigable thunderstorm in a light airplane, the 180 degree turn is not prohibited.

Major Joseph H. Hall graduated from Middle Georgia College in 1939. He is also a graduate of the USAAF Aviation Cadet School, the B–17 and B–29 instructor courses, the Air Force Forecaster's School, and the USAF C–54 transition course. He is a senior pilot, instrument rated, with over 3,500 hours flight time and is qualified in the L–19, LC–126, L–23, C–45, T–6, B–17, B–29, C–54, and the H–13. Major Hall is presently the Commander of Detachment 31, Third Weather Squadron, Ozark Army Air Field, Camp Rucker, Alabama.

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EDITOR-IN-CHIEF

Captain Weyman S. Carver

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Manuscripts, photographs, and other illustrations pertaining to the above subjects of interest to personnel concerned with Army aviation are invited. Direct communication is authorized to: Editor-in-chief, "ARMY AVIATION DIGEST", Army Aviation School, Camp Rucker, Alabama.

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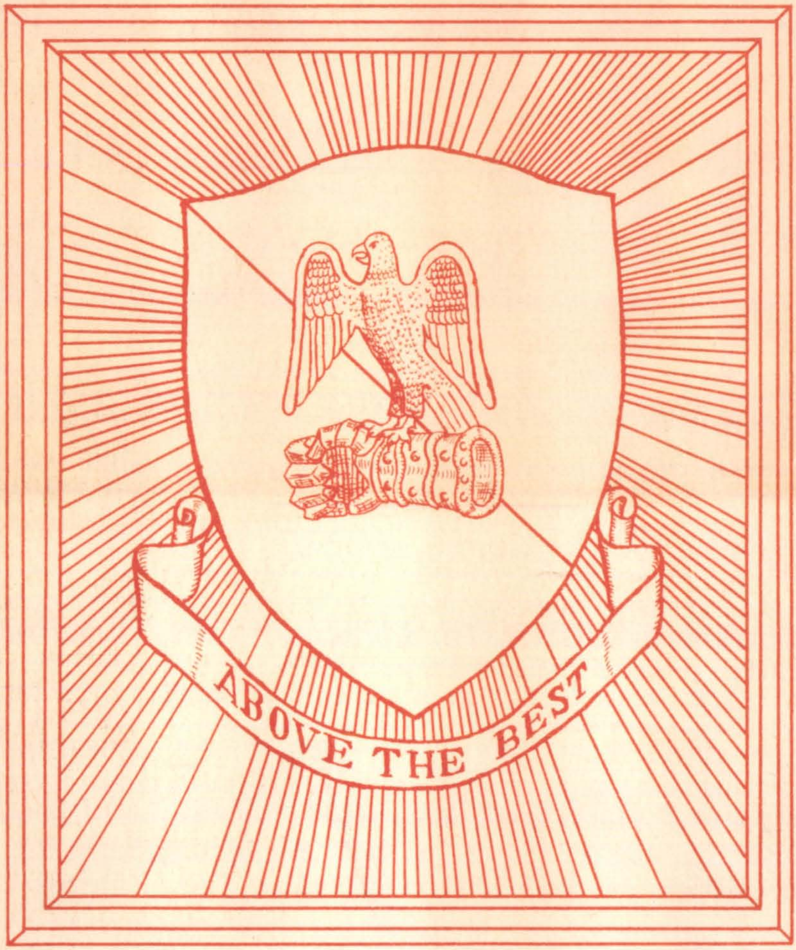

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When reproduced in full color, the colors red, blue, and yellow are used in the crest to indicate representation of all branches of the army in the Army Aviation School. The school's aviation training mission is symbolized by the perched falcon denoting the art of falconry with its patient training of swift, keen birds for hunting. The mailed fist depicts the military commander or ground arm which exercises the control, training, and direction of the flight.